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Experiment Station

SOIL MOISTURE-SOIL TEMPERATURE INTERRELATIONSHIPS ON A SANDY-LOAM SOIL EXPOSED TO FULL SUNLIGHT

Abstract. In a study of birch regeneration in New Hampshire, soil moisture and temperature were found to be intimately related. Not only does low moisture lead to high temperature, but high temperature undoubtedly accelerates soil drying, setting up a vicious cycle of heating and drying that may prevent seed germination or kill seedlings.

In studies of regeneration, lack of germination or seedling mortality often is attributed either to critically low soil moisture or to extremely high soil temperatures. However, these factors do not operate independently; extremes of one factor seldom occur without corresponding, although opposite, extremes in the other. Evidence of this relationship was found during a birch regeneration experiment on the Bartlett Experimental Forest in New Hampshire.[1] Certain data from that experiment are presented here as an aid to the further understanding of some of the environmental factors affecting the regeneration process.

[1]Marquis, David A. GERMINATION AND GROWTH OF PAPER AND YELLOW BIRCH IN SIMULATED STRIP CUTTINGS. U. S. Forest Serv. Res. Paper NE-54, 19 pp. NE. Forest Exp. Sta., Upper Darby, Pa., 1966.

Study Methods

The regeneration experiment from which these data were taken involved evaluation of seedling responses under artificial screens that had been set up to simulate various types of clearcut openings. Only data from the full sunlight treatment, which was replicated four times, are used here. At each replication, four 6-inch clay flower pots set flush with the ground constituted a plot. Two of each set of four pots were allowed to vary naturally in soil moisture while the other two were maintained near field capacity. The latter condition was achieved by nesting the clay pot in a slightly larger plastic flower pot in which several inches of water were maintained as a reservoir.

The soil for the study was from the B_2 horizon of a Hermon sandy loam. In preparation for use, the soil was dried, thoroughly mixed, passed through a 1/4-inch mesh sieve to remove stones, supplemented with lime and fertilizer, and then placed in the pots and compacted slightly to a bulk density of about 1.0. Field capacity of the soil when thus prepared was 48 percent by volume as determined on a tension table at 60 cm. tension. The wilting point was 9 percent by volume as determined in a pressure membrane at 15 atmospheres pressure.

Cooper-constantan thermocouples placed at the soil surface and 1-inch below the surface were used for soil-temperature measurements. Coleman Fiberglas soil-moisture units were placed on edge in the top inch of soil for moisture measurements. The Coleman units were calibrated against gravimetric determinations in the laboratory. Moisture and temperature measurements were taken three times a week at 12 noon EST, May through September. Germination tests also were run in these same pots, so the moisture and temperature data were not bare-soil readings toward the end of the growing season. However, the effect of the seedlings was slight because they were limited to a maximum of nine per pot and their average height was less than 1/2 inch at the end of the growing season.

A complete series of measurements was taken during each of three growing seasons: 1962, 1963, and 1964. Differences in average moisture and temperature were tested for significance with the analysis of variance under a split-plot design. A probability level of 0.05 was accepted for significance. Further details on study methods are presented in the report on the regeneration phase of the study.[1]

Results and Discussion

Maintenance of soil moisture near field capacity by supplemental watering caused a significant reduction in surface soil temperatures (table 1). Noon temperatures throughout the three growing seasons averaged 10°F.

Table 1.—*Average noon-time soil moisture and soil temperature in full sunlight*

Year	Soil moisture: Natural moisture regime	Soil moisture: Supplemental moisture regime	Soil temperature: Natural moisture regime	Soil temperature: Supplemental moisture regime
	Percent[1]	*Percent*[1]	*Degrees F.*	*Degrees F.*
1962	26	42	88	83
1963	20	44	93	82
1964	17	48	98	84
All 3 years	21	45	93	83

[1]Percent by volume.

cooler on the moist soils. During 1964, the driest of the three years, they averaged 14°F. cooler. These average figures do not show the extreme differences that frequently occurred, because the figures include cloudy as well as sunny days, and periods when recent rainfall equalized moisture on the two treatments. On many individual days, differences in excess of 40°F. were observed. These findings agree fairly well with Maguire's report of reductions in surface soil temperature of as much as 50°F. after rain or artificial watering.[2]

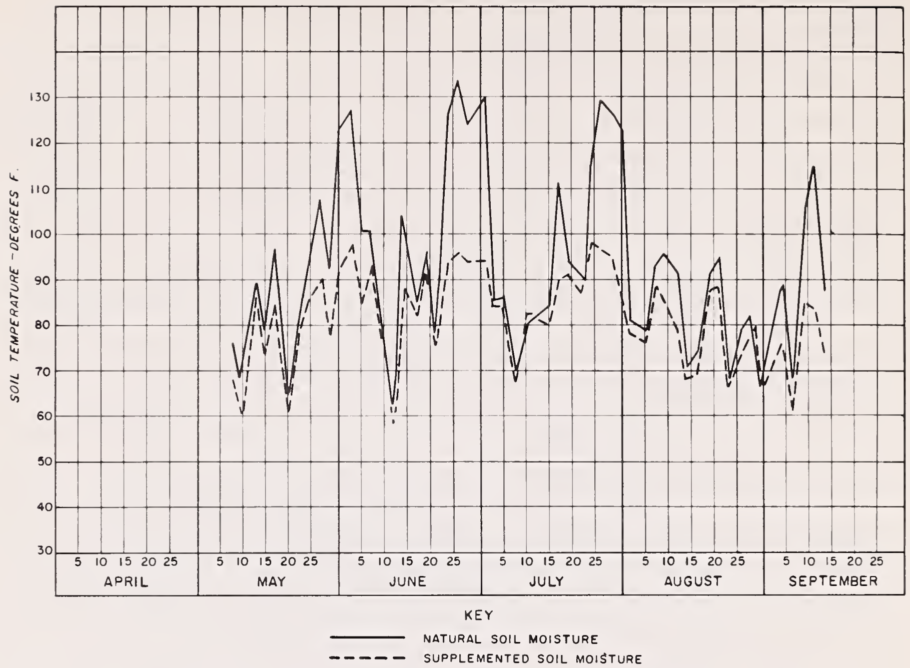
The effect of moisture on average temperature is also apparent in the data for the unwatered plots during each of the 3 years. Average moistures for the consecutive years were 26, 20, and 17 percent; and average surface soil temperatures for the same years were 88°, 93°, and 98°F., respectively. Thus average temperatures were higher in years of lower soil moisture.

Daily temperature readings over the course of the 1963 growing season (fig. 1) illustrate the differences between the two moisture regimes more effectively than seasonal averages. It is apparent that plots with higher moisture had lower surface temperatures. The primary effect of high moisture was to prevent extremely high temperatures. Plots that received supplemental watering did not exceed 100°F. at any time, while the drier plots with a natural moisture regime occasionally exceeded 140°F. (Maximum temperature of 142°F. occurred during early July 1964.)

A further illustration of the interrelationship between soil moisture and soil temperature is obtained by comparing the two factors on the same

[2]Maguire, William P. RADIATION, SURFACE TEMPERATURE, AND SEEDLING SURVIVAL. Forest Sci. 1: 277-285, 1955.

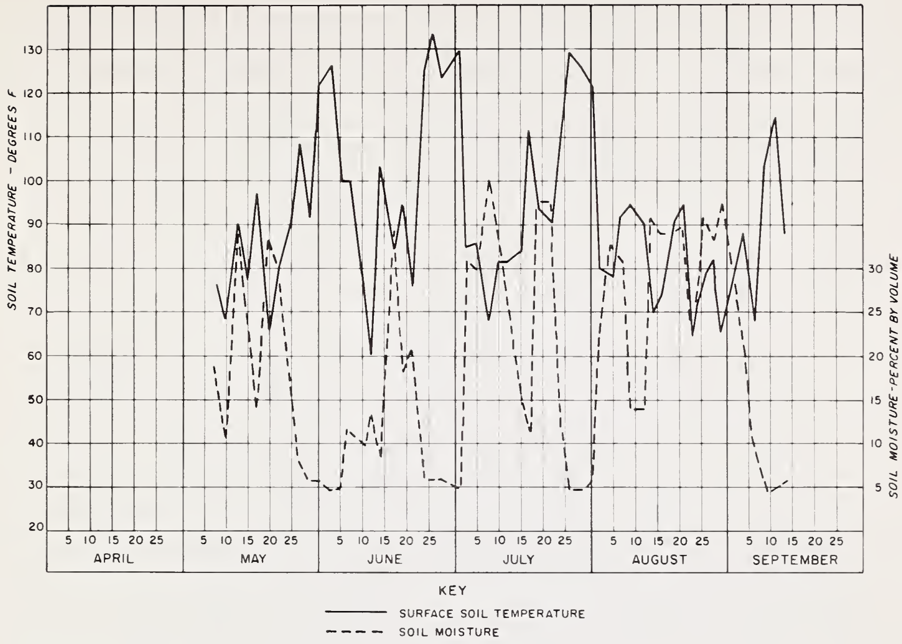
Figure 1.—Surface soil temperatures in 1963 on two moisture regimes.



plots (fig. 2). The two curves are essentially mirror-images of each other. When soil moisture was high, soil temperature remained moderate. But when soil moisture dropped to low levels, temperatures rose extremely high.

This effect of soil moisture in regulating soil temperature probably comes about in at least three ways: (1) On the wetter soil, a large proportion of the incoming energy is spent on evaporation and is not available to warm the soil. (2) Additional water in the wetter soil raises the specific heat of the mixture, requiring more energy to raise a given volume of soil 1 degree. (3) Additional water in the wetter soil increases its thermal conductivity. Therefore heat received at the surface is conducted downward more rapidly; the lower layers are warmed more quickly; and the surface remains cooler than on the dry soil where surface heat is dissipated more slowly. This latter effect is evidenced by a greater spread between surface temperatures and 1-inch temperatures on the dry plots. Average spread over the three seasons was 9°F. on the dry soil as opposed to only 4°F. on the wet soil.

Figure 2.—Soil moisture and soil temperature in 1963 on plots with natural moisture regime.



Although not apparent from the data presented here, the relationship between these two factors probably works both ways. Not only does low moisture lead to high temperature, but high temperature undoubtedly accelerates soil drying, setting up a vicious cycle of heating and drying that may cause seedling mortality or prevent seed germination. Under the conditions of this study, it is unlikely that such effects can be attributed solely to either factor because the two are so intimately related.

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